XXIII. *Defcription of an improved Air-Pump, and the Account of fome Experiments made with it. By Mr.* Tiberius Cavallo, *F. R. S.*

Read July 3, 1783.

THE principal improvements which the air-pump received fince it was firft invented, were contrived by Mr. SMEATON, F. R. S. and are defcribed in the XLVIIth volume of the Philofophical Tranfactions. This ingenious gentleman, confidering the imperfections of the air-pumps ufually made, not only found means to correct feveral of them, but improved almoft every part of the machine, fo as to render it incomparably fuperior to any thing of the kind done before.

It appears, by fome accurate experiments of Mr. NAIRNE, F. R. S. defcribed in the LXVIIth volume of the Phil. Tranf. which were made with an air-pump conftructed after Mr. SMEATON's principle, that by means of the beft air-pumps made before Mr. SMEATON's invention, the rarefaction of the air within the receiver could never have been brought to more than forty or fifty times, if the heat of the place was about 57°; that even with Mr. SMEATON's pump the receiver could not be exhaufted beyond 70° or 80° of rarefaction, when moift leathers were ufed, or moifture was in any way introduced within the receiver; but that when this pump is quite free from moifture, and is newly cleaned, oiled, and put together, then

then the air may by it be rarefied about 600 times, and not farther *.

The principal cause which prevents this pump to exhaust farther than that limit is the weakened elasticity of the air remaining within the receiver, which, decreasing in proportion as the quantity of the air within the receiver is diminished, becomes at last incapable of lifting up the valve, which opens the communication between the receiver and the barrel; consequently no more air can in that case pass from the former to the latter.

To remove this principal imperfection of the best air-pumps had been attempted by several ingenious persons; but, as far as I know, was never obtained before the happy contrivance of the air-pump, which I am going to describe in the following pages.

Being in want of a good air-pump, and imagining that the opening and shutting the communication between the barrel and the receiver might, instead of the valve, be performed by means of a stop-cock, particularly constructed upon an idea of mine; I communicated my plan, about the latter end of the last year, to Mr. JACOB BARNARD HAAS, an ingenious workman in the philosophical-instrument way, who, in partnership with Mr. JOHN HENRY HURTER, had lately established a manufactory of philosophical instruments. Mr. HAAS remarked, that according to my plan the friction of the parts of

* The degree of rarefaction shewed by what is called the pear-gage, when any vapour of water is within the receiver, is not to be considered as the degree of rarefaction of the elastic fluid in the receiver, but only of the air; for though the air may be exhausted, yet the vapour of water will supply its place; we shall, therefore, only take notice of the exhaustion when no vapour or moisture is within the receiver. See NAIRNE's Experiments, Phil. Trans. vol. LXVII.

the machine would be too great, and therefore the pump, if it anſwered at all, was not likely to be durable. In conſequence of this, he conſidered upon ſome plan or other which might anſwer the ſame purpoſe in a better way, and ſoon hit upon a method of lifting up the valve at the bottom of the barrel, and of ſhutting it again at pleaſure; which method being put into execution, has been found to anſwer exceedingly well.

Beſides this capital improvement, his air-pump is rendered altogether more convenient for philoſophical experiments, by anſwering ſeveral purpoſes, which will be enumerated after its deſcription.

Plate I. ſhews a perſpective view of this pump. Plate II. exhibits a geometrical delineation of its metal or working parts detached from the wooden frame. And plate III. repreſents a ſection of its parts. The letters of reference are made to anſwer to the ſame parts in all the plates.

In plate III. fig. 1. AABI is the barrel of the pump, to the brood or flat ends of which are ſcrewed, by means of five ſcrews, the pieces CE and K, with leathers between, to render the junctures perfectly air-tight *. The upper piece CE contains the collar of leathers for the handle or axis GG of the piſton to go through, and the baſin F, which ſerves for a cap to ſcrew down the leathers, at the ſame time that it holds the oil, which may be put into it, in order to let the collar of leathers hold very tight; though it is ſhewn, by experience, that when the leathers are perfectly ſoaked, there is not the leaſt occaſion to keep any oil in the baſin F. The ſame upper piece

* All the leathers uſed for this pump are ſoaked in melted hog's lard; and when the parts of the inſtrument are put together, a little oil is ſmeared upon thoſe ſurfaces of the braſs pieces which go againſt the leather, though this oil may be ſpared.

CE

CE contains the valve at E, which lets the air pass upwards, but prevents its return, and which is so contrived as that, when the piston is drawn quite to the top of the barrel, the least possible quantity of air should be left into the barrel. The parts which form this valve are shewn separately in fig. 3. where 1,3 is a brass piece that screws into a proper cavity made for its reception in the piece CE, and which is hollow, except its lower part, where it consists of a thin lamina perforated with a small hole 3. Into the hollow of the last mentioned part is screwed the other perforated piece 2,4, having a slip of oil-silk stretched over its lower part 4, and tied round a small indenture or groove made on its lower part. This slip of oil-silk answers better than a piece of bladder or leather: it just covers the hole 3, and is about four times broader than the diameter of the hole.

It will be easily conceived, that when the air is forced through the hole 3, it will lift up the slip of oil-silk, and passing by the sides of it, and also through the large perforation of the piece 2,4, will go upwards, &c.; but can by no means return backwards, since any pressure, that the air makes on the upper part of the oil silk, will only stop the passage more effectually.

A valve much like this is in the piston, the parts of which are shewn separately in fig. 4. *u* is a perforated brass piece screwed to the cylindrical handle or axis GG, which is also perforated with a short and bent hole. The piece *x* is screwed into the part *u*, and contains a valve, *viz.* a small piece 6 with a slip of oil-silk tied round its groove *yy*, which slip of oil-silk bears against the hole 5. The piece *x* screwing into the other piece *u*, fastens the round leathers which, about thirty in number, form the stopping part of the piston, and rub with their edges against the cavity of the barrel. This is a very useful improvement,

ment, ſince the common way of uſing two leathers turned over corks is both troubleſome to make, and ſeldom fits exactly.

The piece K faſtened to the lower end of the barrel is perforated with a hole, the direction of which is clearly ſeen in the figure, and which communicates with the perforation of the round piece L, which is ſcrewed to K with a leather between. The perforation therefore of K communicates with the cavity of the braſs tube RS, this being ſoldered to L. The part of the piece K, which projects within the barrel, is ſmaller in diameter than the cavity of the barrel, and the intervening ſpace is exactly fitted by the moveable ring 8, 8, the two parts of which are ſcrewed together, holding faſt between, the edge of a piece of oil-ſilk, which ſtretches over the upper part of the piece K, and covers its aperture. A vertical view of the above-mentioned oil-ſilk, with five holes in it, is ſhewn in fig. 6.

It appears from this deſcription, that the air can paſs through the valve from without to within the barrel, but not *vice verſâ*. It will be alſo eaſily conceived, that the air can paſs from the cavity of the tube R through the perforation of the pieces L and K, within the cavity of the barrel, only when the ſaid air has elaſticity, or force enough to puſh up the oil-ſilk. Now the principal improvement in this machine is, to lift up the oil-ſilk by a power applied externally, when the weakened elaſticity of the air within the cavity of the tube R, &c. is not capable of doing it by itſelf, and here follows the deſcription of this mechaniſm.

The double ring 8, 8, which holds the oil-ſilk, is faſtened to two ſteel wires 9, 9, which are ſhewn in fig. 5.; this figure being a ſection of the lower part of the pump through a plane perpendicular to the plane of the ſection, fig. 1. Thoſe wires

paſs through collars of leathers held in proper braſs boxes HQ, ſcrewed to the piece K, and furniſhed with caps, 11, 11. The lower extremities of the wires are faſtened to the croſs bar, 7, 7, of the braſs frame, OOO, a vertical view of which is ſhewn in fig. 4. of plate II.

From the middle of the piece L, fig. 1. pl. III. a pillar M proceeds, the lower part of which, branching into two horizontally, forms an axis *z*, *z*, fig. 4. pl. II. about which the braſs frame OOO moves a little way upwards and downwards.

It appears from this deſcription, that if the frame OOO fig. 4. pl. III. is moved upwards, the wires 9, 9, and likewiſe the double ring 8, 8, with the oil-ſilk, being all connected together, will be puſhed alſo upwards; conſequently, the oil-ſilk being removed from the hole of the piece K, a free communication is opened between the cavity of the tube R, and the cavity of the barrel, through which the air, however rarefied or weakened in elaſticity, can paſs without the leaſt impediment.

In order to move the braſs frame upwards, the end of a lever P bears againſt it. This lever is ſhewn in fig. 3. of plate II. which is a front view of part of the pump, whereas fig. 1. of the ſame plate is a ſide view of it. The center of motion of the lever is at 13, that is, between two ſide prominences of the piece 12, 12, which is faſtened by ſcrews to one of the wooden pillars of the frame of the machine. The part 15 of the lever, which projects beyond the wooden pillar, is made with a joint, by which means it may be turned upwards, as repreſented by 17, for packing it more conveniently.

When the valve is to be opened, the foot of the operator muſt preſs upon the extremity 15 of the lever, by which means the other extremity P, the frame OOO, the wires 9, 9, and the double ring 8, 8, with the oil-ſilk, are all lifted up. But in order

order to bring down again all thoſe parts, and to ſhut the valve when the preſſure of the foot is removed, there is an open braſs tube N, faſtened to the piece K, which contains a ſpiral ſpring, that, bearing againſt the extremity of the braſs frame OO, puſhes it downwards.

This principal mechaniſm being diſpatched, it will be very eaſy to deſcribe the remaining parts of this excellent machine: but before we proceed to that, I ſhall briefly deſcribe another mechaniſm, which Mr. HAAS has lately contrived, to ſupply the place of that juſt mentioned, *viz.* of the lower part of the inſtrument, as being much more ſimple, and capable of anſwering the ſame purpoſe.

A ſection of this new thought, which he is going to execute for another pump, is ſhewn in fig. 7. of plate III.

AB is the lower extremity of the barrel. CCDE is a piece of braſs perforated quite through with a large and cylindrical hole, and is ſcrewed to the barrel inſtead of the piece K of fig. 1. with a leather between. On one ſide of this piece CDE, part of the ſurface is flattened, and to it is adapted, by means of ſcrews and a leather, the piece of braſs G, to which the tube H is ſoldered, which correſponds to the tube RS of fig. 1. The aperture of CC, towards the cavity of the barrel, is covered by a piece of oil-ſilk, like that repreſented in fig. 6. which is kept ſtretched by a braſs ring LL, ſunk into the piece CCD.

Within the cylindrical perforation of the piece CCDE, there is a long piſton KI*r*, conſiſting of the following parts. IK is its axis, which ſpreads at top into a flat plate *r*, and the lower extremity of which is faſtened at N to the lever MO, which moves round the center M. Towards the middle of the axis, there is a piece of braſs, the ſhape of which is more eaſily

 underſtood

understood by inspecting the figure, than by a verbal description, which piece confines the round leathers from itself to the plate *r*, and also from itself to the other plate, which is screwed upon the axis at K.

Between the last mentioned plate and the cap F, there is a spiral steel spring, which always pushes the piston upwards. Lastly, the axis of the piston is perforated from its top till towards the middle, where the perforation, opening side-way, communicates with the cavity of the tube H.

Now, when the piston is pushed upwards, as it always is when the extremity O of the lever is not pressed down, then the oil-silk at LL, laying against the plate *r*, covers the hole of the piston, consequently it shuts the communication between the barrel and the cavity of the tube H, &c. But if this communication is required to be opened, then the extremity O of the lever is pressed down, which will separate the upper part of the piston from the contact of the oil-silk, so as to open the communication as required.

Let us now return to the description of the other parts of the machine, as shewn in fig. 1. The upper extremity *o* of the tube RS is made conical, and is fitted by grinding into the strong brass piece of communication UX*l*; the cap T serving to tighten it*. The extremity *n* of the opposite piece *np* is likewise fitted by grinding into the part *l*, and is tightened by the cap *m*. Just over the said conical extremities *n* and *o*, and into the same piece of communication UX*l*, are adapted two stop-cocks Z and *h*, which are tightened down by the caps

* All the parts of this pump, that are fitted to each other by grinding, as the stop-cocks, the extremity of the tube RS, &c. before they are put together, are smeared with a mixture of bees-wax and oil melted together, in order to let them stop the better, and to prevent their wearing by friction.

Y and *i*; but as thoſe ſtop-cocks muſt be turned by means of a key adapted to their ſquare tops, and in that caſe their friction againſt the caps would unſcrew or tighten them; therefore a ring is put round each cap, which ring is prevented from turning by a pin, and is faſtened round the cap by means of a ſcrew with a milled head. Theſe rings are ſeen in fig. 1. of plate II. Each of the ſtop-cocks is perforated with a hole, which goes from one ſide to the bottom of it.

The upper part of the piece of communication terminates in a ball *a*, into which the lower and conical extremity *b* of the tube *d* is adapted by grinding, and is faſtened by the cap *c*. The tube *d* is ſoldered to the part *e*, which is made faſt to the upper board of the frame of the machine, and to which the plate *ff*, having the rim *gg*, is ſcrewed with a leather between.

The lower part of the piece *np* is ſcrewed with a leather between to the top of the ſtrong braſs veſſel *qrs*, and is terminated as appears in the figure, for a reaſon that will be made evident in the ſequel. The veſſel *qrs* is faſtened to the middle ſhelf of the wooden frame by ſcrews *ss*; and it has a perforation at bottom, which is ſhut by the ſcrew nut *t*, and ſerves to let out the oil, which, after working the machine for ſome time, will be found lodged in the veſſel *qrs*.

The tube E*r* is ſoldered into the piece D, and likewiſe into the veſſel mentioned above, wherein it proceeds till very near the top of the veſſel, where it opens.

The piſton of the pump, with its axis GG, is moved upwards and downwards by means of the rock-work, wheel, and handle; which parts being clearly ſhewn in fig. 1. and 2. of plate II. and alſo being nothing new, require no farther deſcription.

To the fore-side of the ball *a*, on the strong piece of communication, is adapted by a cross-piece and a screw, the gage which shews the exhaustion of the pump. This gage may be seen in fig. 1. of plate II. It consists of an outward glass tube containing a little quicksilver; and of an inside tube, which, like a barometer, is filled with, and inverted into, the quicksilver of the large tube. The inside tube is supported at top by a spring socket. A small ivory scale, with divisions, encompasses the small tube, and swims upon the surface of the quicksilver in the large tube. By means of this scale the exhaustion of the pump may be begun to be measured, after that the air is rarefied at least thirty times.

To the other side of the ball *a*, *viz.* opposite to the gage, there is a screw-nut, which, by means of a leather, shuts a hole made in the said ball, and serves to open the communication between the receiver and the atmosphere. This nut, besides a milled head, has a square filed on it, to which a key may be applied, in order to open the screw more easily, and by degrees without jerks, which can hardly be avoided when the nut is opened by one's finger applied immediately to it. This nut is seen in plate I.

I shall forbear from any more prolix description of other gages that may be adapted to this pump, as also of other parts necessary for performing experiments with it, these things being very well known at present, and containing nothing new.

Now, as to the working of this pump, a bare inspection of fig. 1. in plate III. will shew, that by the action of the piston, when moved up and down into the barrel, the air will be exhausted from the cavity of the tube RS, of the ball *a*, tube *d*, and of course from the glass receiver that is put upon the plate *ff*; for when the piston, after being let down, is drawn upwards,

 the

the under part of the barrel remains without any air; consequently the valve at the bottom of the barrel, having no pressure on one side, will be pushed up by the air in the receiver, which expanding comes through the tube RS, and part of it passes into the barrel. Then the piston on being let down, the air passes through the valve of the piston, to the upper part of the barrel, and when afterwards the piston is drawn up, this air is forced through the valve at E into the tube D*r*, from thence into the vessel *qs*, through the channel *pn*, and, lastly, it will be expelled into the atmosphere through the aperture *k*.

As some small quantity of oil is always necessary to be put into the pump, this oil, by the action of the piston, is brought, together with the air, towards the tube D*r*, and would come out of the hole *k* if the vessel *qs* had not been placed to receive it; and it is for this reason, that the lower part of the piece *pn* is shaped as shewn in the figure, and that the tube D*r* is made to proceed almost as far as the top of the vessel *qs*; for if the oil was permitted to come out of the aperture *k*, it would be scattered about the instrument and the operator, by the violence of the air coming out of *k*.

As this pump exhausts exactly in the same manner as other pumps do, the lever which opens the valve at the bottom of the barrel is not to be moved, except when such a degree of exhaustion is required as cannot be made by the instrument itself, *viz.* when worked in the ordinary way. In fact, it will be seen by the gage, that when the mercury cannot fall any lower by the usual way of working the pump, it will be instantly depressed by opening the valve at the bottom of the barrel, which evidently shews the great advantage of the improvement. In general, the lever may be begun to be pressed, or, which is the same thing, the valve to be opened, when the gage

gage ſhews that the exhauſtion of the air is to about 100 times, *viz.* that the quantity of the air remaining within the receiver is about the one-hundredth part of the air that was contained in it before the exhauſtion was commenced. Care muſt be taken to open the valve only whilſt the piſton is drawing up, and to remove the foot from the lever the moment that the piſton is impelled downwards, otherwiſe the work is uſeleſs.

In the ſituation in which the pump is ſhewn by fig. 1. pl. III. it is evident, that as the action of the pump determines the air to move from the tube RS into the barrel and from the barrel up the tube D*r*, &c.; it is evident, I ſay, that if a receiver is placed upon the plate *ff*, the air will be exhauſted from it. But if the ſtop-cocks Z and *h* are ſo turned as that the ſide hole of the cock *h*, as well as that of the cock Z, is turned towards X, then, by the action of the pump, the air, inſtead of being exhauſted, is condenſed into the receiver properly placed upon the plate *ff*; for now the air coming from the atmoſphere through the aperture X goes down the cavity of the tube RS, enters the barrel, and from the barrel is impelled upwards through *Dr*, through *pn*, through *a*, *b*, *d*, and laſtly into the receiver, which in that caſe muſt be preſſed down, as is uſually done in condenſing engines. This ſituation of the ſtop-cocks, *viz.* when the inſtrument is to be uſed as a condenſer, is ſhewn in fig. 2. of plate III. Two letters, E and C, marked upon the ſquare top of each cock, direct the operator how to turn them, whether for exhauſting or for condenſing.

The conical holes X and *k*, fig. 1. plate III. are made to receive occaſionally the extremities of two ſtop-cocks. Thoſe ſtop-cocks are fitted to the holes H and *k* by grinding, and a bladder is adapted to each of them. The uſe of this contrivance is to introduce into the glaſs receiver ſome particular ſort of

of elaſtic fluid, or to receive into a bladder the elaſtic fluid that is contained in the receiver. Thus, ſuppoſe I want to introduce ſome fixed air into the receiver; firſt, I exhauſt the common air from the receiver, then put the ſtop-cock of a bladder containing fixed air to the hole X; laſtly I open the ſtop-cock of the bladder, and turn the cocks *bZ*, ſo that their ſide-holes may be turned towards X, and by working the pump the fixed air will immediately paſs from the bladder into the receiver. If now this ſame fixed air is required to be introduced into a bladder again, the ſtop-cocks muſt be turned with their ſide holes towards *k*, and a ſtop-cock with an empty bladder is put to the hole *k*; then, by working the pump, the fixed air will be gradually introduced from the receiver into the bladder.

Having finiſhed the deſcription of this improved air-pump, which, beſides its exhauſting much better, has various other advantages over any other inſtrument of the kind; I ſhall conclude this paper with the ſuccinct account of ſome experiments made with it, principally to determine how far it can rarefy the air.

Experiments made with the above-deſcribed air-pump.

Previous to the narrative of the experiments, it is neceſſary to mention, that both the plate, and the lower edges of the receivers of this pump, are ground ſo perfectly true, as not to require any leathers, nor even oil; however, for greater ſecurity, ſome oil is generally poured on the outſide of the edge of the receiver, after having exhauſted it a little; and it is very ſeldom, that any viſible quantity of this oil paſſes within the receiver, between its edge and the plate of the pump.

 When

When the hole in the plate of the pump is ſtopped up by means of a ſcrew and leather, and the inſtrument is worked for about three or four minutes, the quickſilver in the ſmall tube of the gage falls ſo low as to be even with the quickſilver in the outſide tube, which ſhews as if the air were entirely exhauſted from the inſide of the pump; but as it is difficult to judge whether the two ſurfaces of the mercury in the inſide and outſide tube are quite on the ſame level, and even if they were exactly ſo, there could always be ſuſpected that a little air may be lodged within the gage, notwithſtanding that ſeveral gages of this ſort have been uſed, in ſome of which the mercury had been accurately boiled; we muſt, therefore, have recourſe to other gages, in order to determine the exhauſting power of this pump with more preciſion. Accordingly, the pear-gage and long barometer-gage were tried, the effects of which will be related in the ſequel.

If, inſtead of ſtopping up the hole in the plate of the pump, a glaſs receiver is laid upon it, and the pump is worked, the gage will alſo come ſo low as when no receiver is put upon it; but it muſt be remarked, that after exhauſting and leaving the inſtrument in that ſtate, when no receiver is upon it, the quickſilver in the gage will be riſing for about one hour, ſo as to aſcend one-tenth, or at moſt one-fifth of an inch above the ſurface of the quickſilver in the outward tube, and then it remains ſtationary; whereas if the experiment be repeated when the receiver is upon the plate, the degree of exhauſtion remains unaltered, the mercury not riſing at all in the ſmall tube. This riſing of the quickſilver in the firſt caſe ſeems to be occaſioned by ſome ſmall quantity of elaſtic fluid, that is yielded by the oil contained between the parts of the machine; for this quantity of elaſtic fluid can occaſion a ſenſible difference when the

exhauſted

exhausted space within the pump is small, but it becomes quite inconsiderable when the receiver is upon the plate, its quantity bearing a very small proportion to the exhausted space.

It is of great advantage in this pump that very little oil can be lodged in it, because then the elastic fluid yielded by this fluid is in so small a quantity as not to affect the experiments. As for the oil, which by the working of the pump is accumulated into the oil vessel, it cannot interfere with the exhaustion of the pump, since it does not communicate with the cavity of the receiver.

The exhausting power of this pump was next examined with the pear-gage, made and placed under a receiver after the usual manner; and by this it appeared that the pump exhausted so far as to remain within the receiver less than the thousandth part of the air it contained before the exhaustion *. In that case, the quicksilver in a short barometer-gage came to the same level in both tubes, which proves that, by this last mentioned gage in that state, the air is shewn to be rarefied at least one thousand times.

Lastly, a long tube, or what is called a long barometer-gage, was adapted to the pump by means of a bent brass tube. This glass tube went down along the side of the wooden frame, and its lower end was immersed in some quicksilver kept in a proper cistern.

On working the pump, when all the three gages were annexed to it, there appeared, that the quicksilver of the short gage came to the same level in the inside as well as outside tube,

* Whenever the pear-gage was used, care was taken to keep the inside of the receiver, of the pear-gage, and of the pump, as free from moisture as it was possible.

that the quickfilver in the long barometer-gage came as high as it ftood at in a real barometer, and that the pear-gage indicated a degree of rarefaction about one thoufand. But as it was not known, whether the quickfilver had been boiled into the tube of the barometer, to which the long barometer-gage had been compared, therefore a barometer was accurately made for that purpofe. The glafs tube had been juft drawn at the glafs-houfe. It was perfectly clean; the quickfilver was boiled in the whole length of it, and care was taken that the dimenfions of the tube, ciftern, and divifions, were alike both in this barometer and in the gage. This done, the pump was tried again, and the quickfilver in the long gage rofe within one-twentieth of an inch of the quickfilver in the barometer, or rather lefs, which fhews that the air was rarefied little above 600 times; but at this time the pump was not in proper order for trying fuch nice experiments. It was leaky, and had not been taken to pieces and cleaned for above fix weeks, in which time it had been frequently ufed, and continually left expofed to the duft of a working-fhop: yet it fhews, that in thefe unfavourable circumftances this pump can rarefy the air above 600 times.

Confidering all the above-mentioned circumftances and experiments, I think it may be concluded, that this pump, when in good order, can rarefy the air about one thoufand times.

I fhall, laftly, conclude this paper with a fummary account of feveral electrical experiments, which were made with this pump; referving to give a more ample and circumftantial account of them for another opportunity.

When the air-pump was in good order, a glafs receiver, which had a brafs cap cemented to its upper aperture or neck, was laid upon the plate; then the end of the prime conductor of an electric machine was placed within half an inch of the

cap

cap of the receiver; ſo that when the machine was in action, the electric fluid in the form of ſparks went from the conductor to the braſs cap, and when the receiver was exhauſted, it paſſed from the cap to the plate of the pump through the receiver, illuminating its whole cavity. The more perfect the vacuum was made, the better conductor of electricity it became, and the electric light was more equably diffuſed in it; but it became by no means faint, even when the receiver was exhauſted to the utmoſt, though the light changed appearance according as the receiver was more or leſs exhauſted. Thoſe appearances were as follows.

Degrees of rarefaction as ſhewn by the ſhort gage.	Appearances of the electric light within the receiver.
Air rarefied 40 times.	Light in large, long, but divided, ſtreams.
70	Fine diffuſed light, of a white colour.
80 100 400	Beautiful diffuſed light inclining to red or purple, and filling the whole receiver.
When the gage ſhewed the utmoſt degree of exhauſtion.	A diffuſed light, filled equally every part of the cavity of the jar. It had hardly any reddiſh hue.

In this ſtate, or even when the air within the receiver was rarefied not above 100 times, if the braſs cap of the receiver was made to communicate with the ground by means of good conductors in perfect contact, the light within the receiver occaſioned by the electric ſparks given by the prime conductor to the cap of the receiver was thereby diminiſhed, but it did

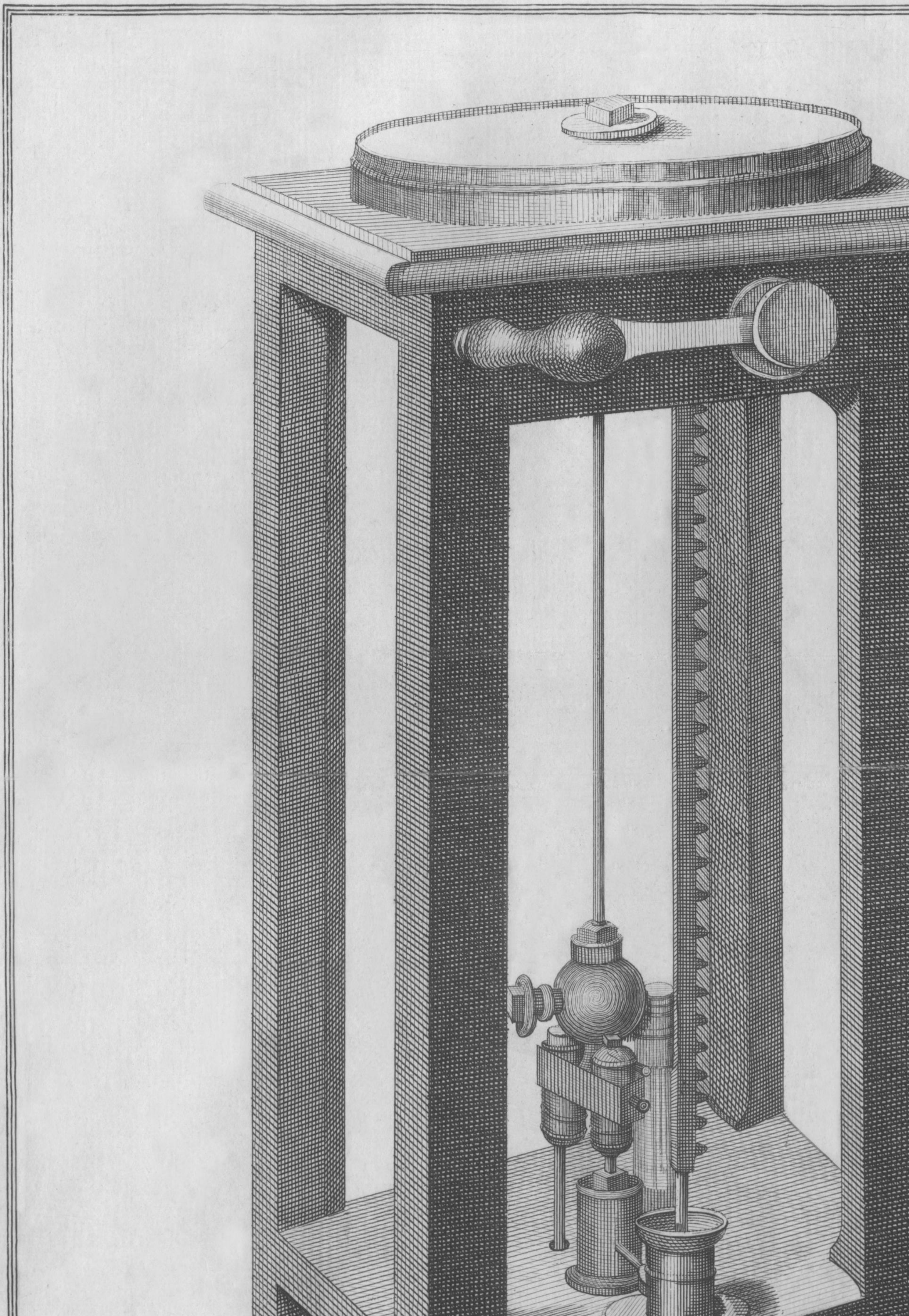
not

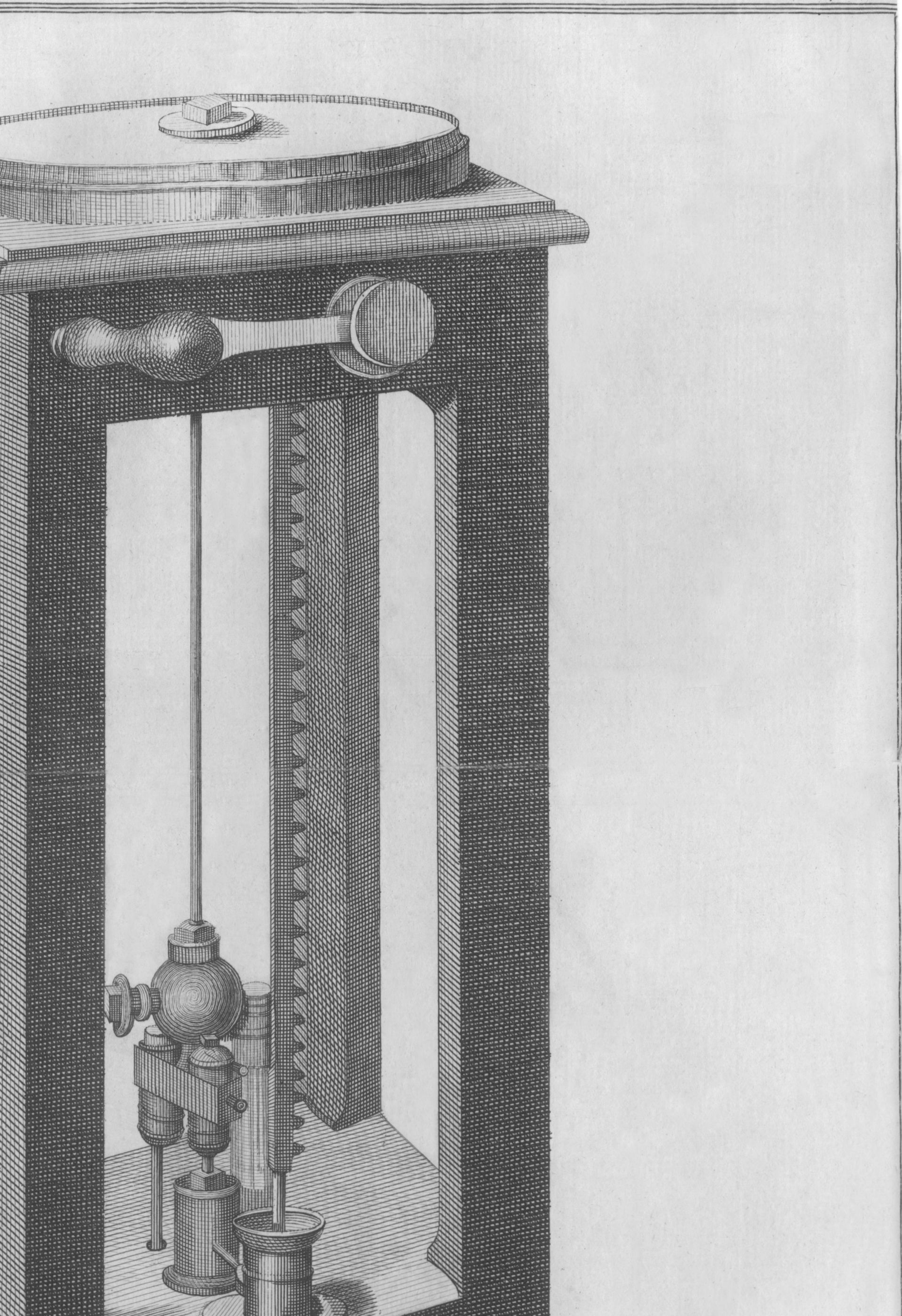
not intirely vanish; which shews, that the electric fluid, which proceeded from the conductor to the cap of the receiver in the form of sparks, did not pass to the earth all through the conductor, by which the cap was made to communicate with the ground; but part of it went at the same time through the vacuum, so that when the pump in this experiment was insulated, sparks could be drawn from the plate of it.

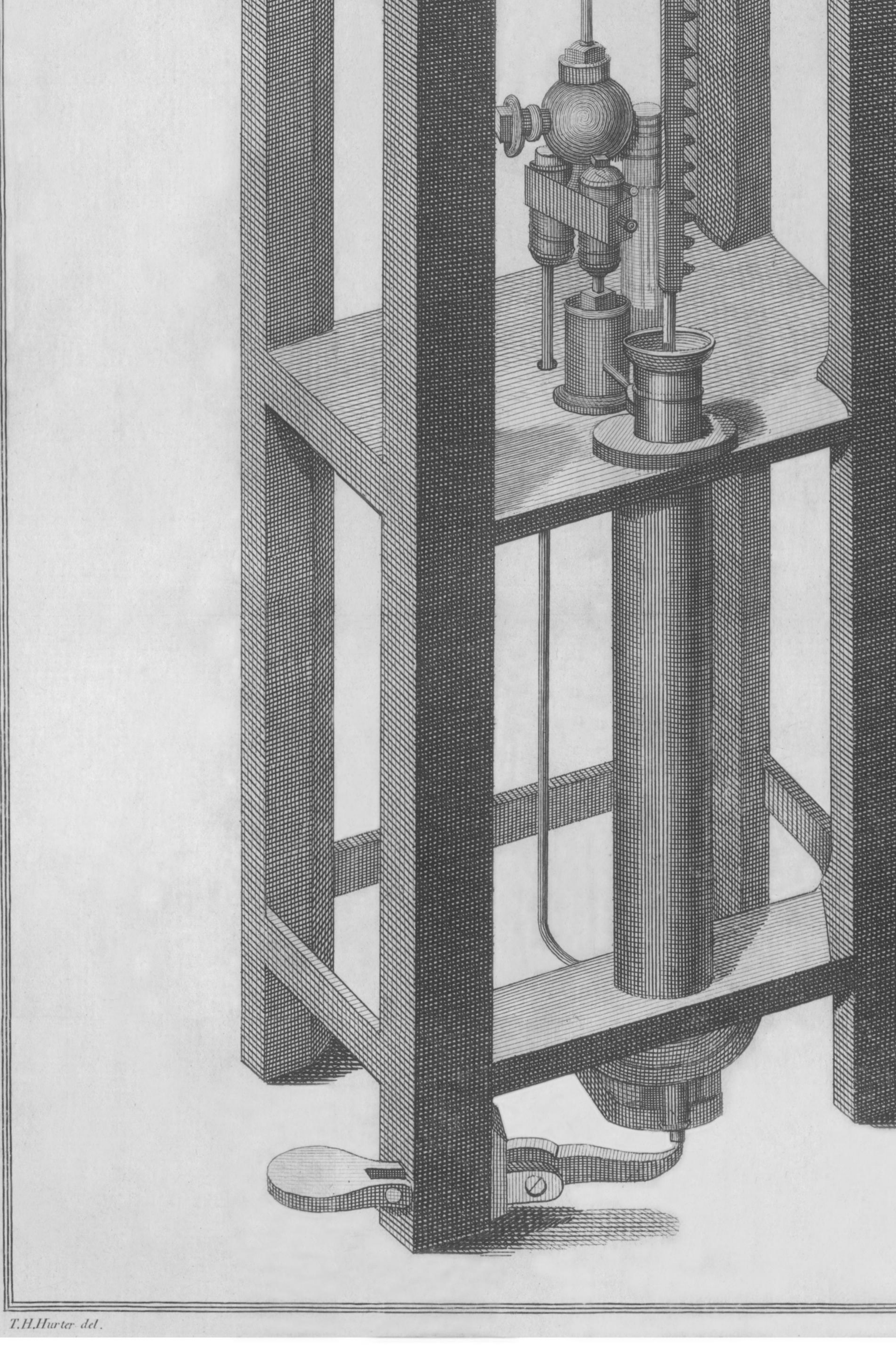
Having repeated the above mentioned experiments with only this variation, *viz.* that the extremity of the prime conductor was put in contact with the cap of the receiver, the appearances of electric light within the receiver were very nearly the same as in the preceding experiments; but if now the cap of the receiver was made to communicate with the ground, the light within the exhausted receiver vanished intirely, though the electrical machine acted very vigorously.

When a pith-ball electrometer was suspended within the receiver from its brass cap, and some electricity was communicated to the outside of the said cap, its balls diverged very little when the air within the receiver was rarefied about 100 times; their repulsion was hardly discernible when the air was rarefied about 300 times; but in a greater degree of rarefaction they did not diverge in the least, and that was the case whether a small or a large quantity of electric fluid was communicated to the cap of the receiver.

June 24, 1783.







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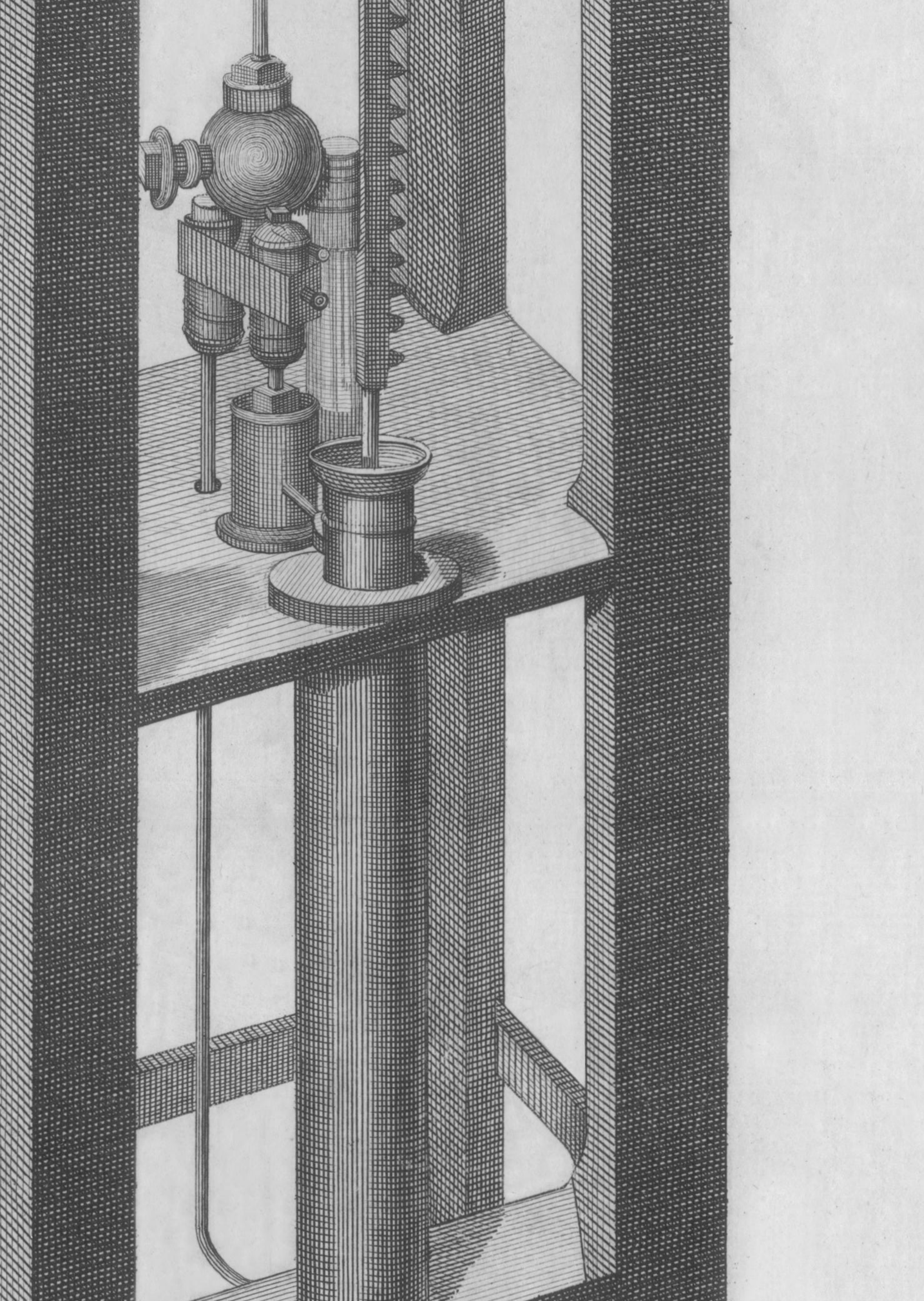

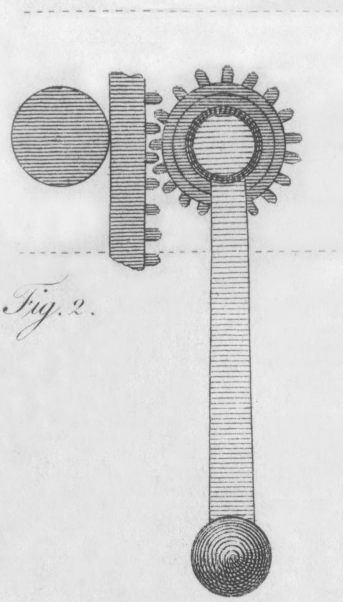

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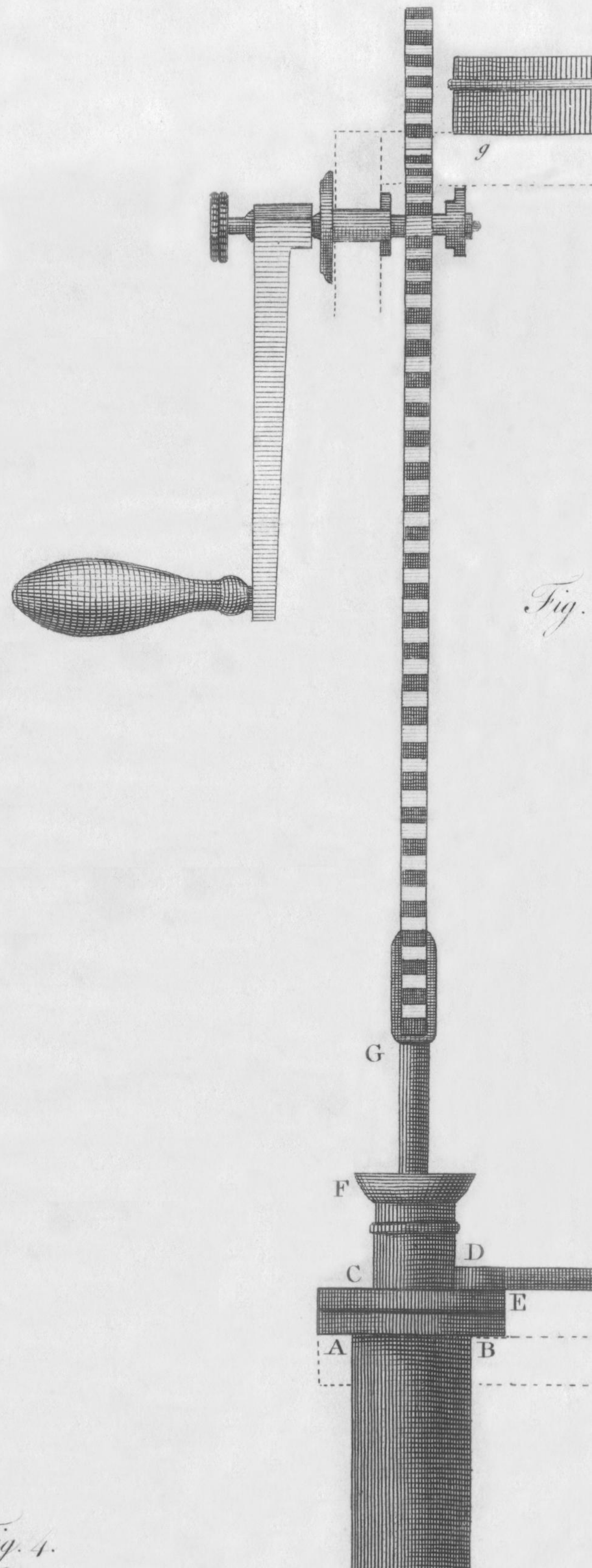

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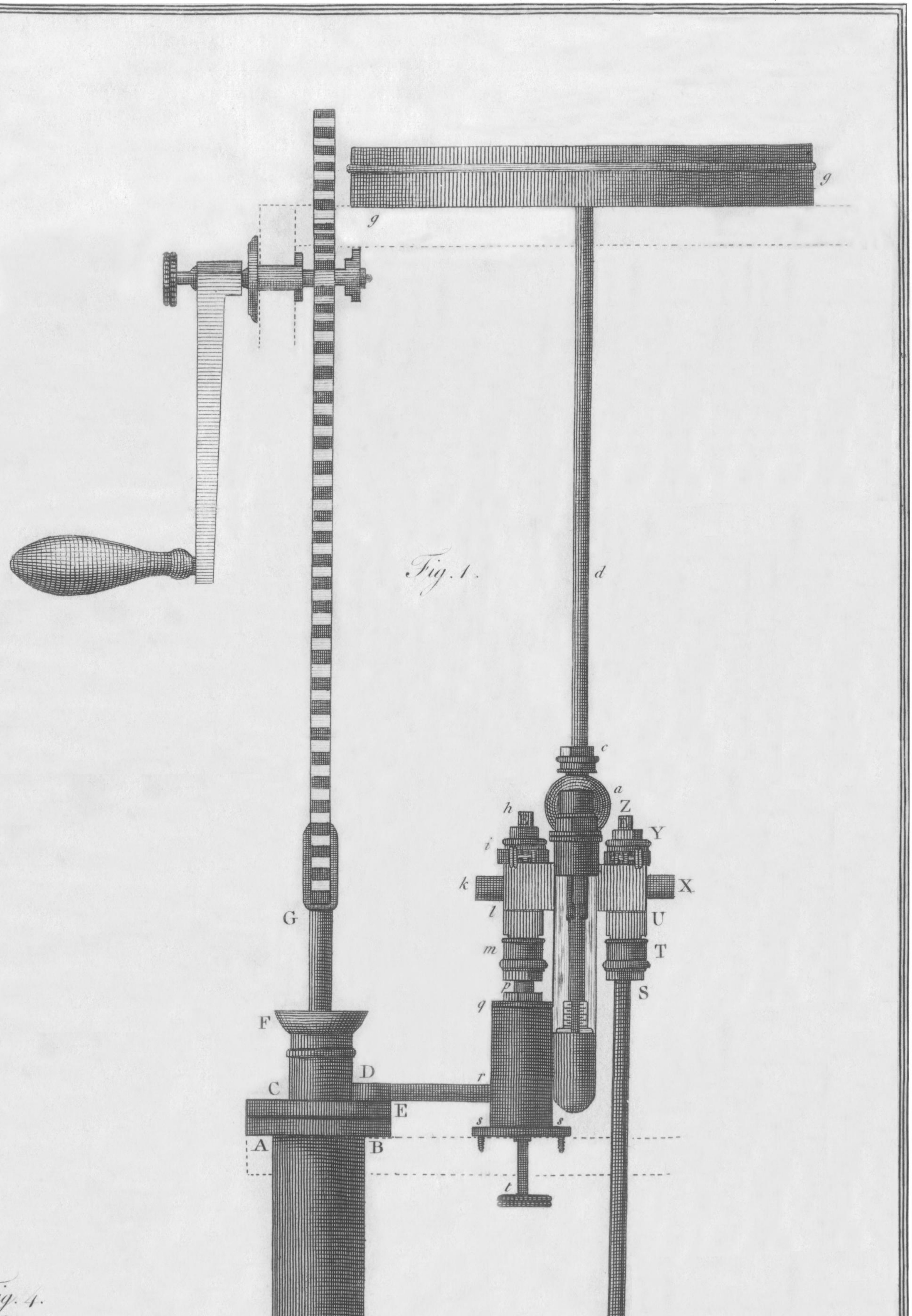
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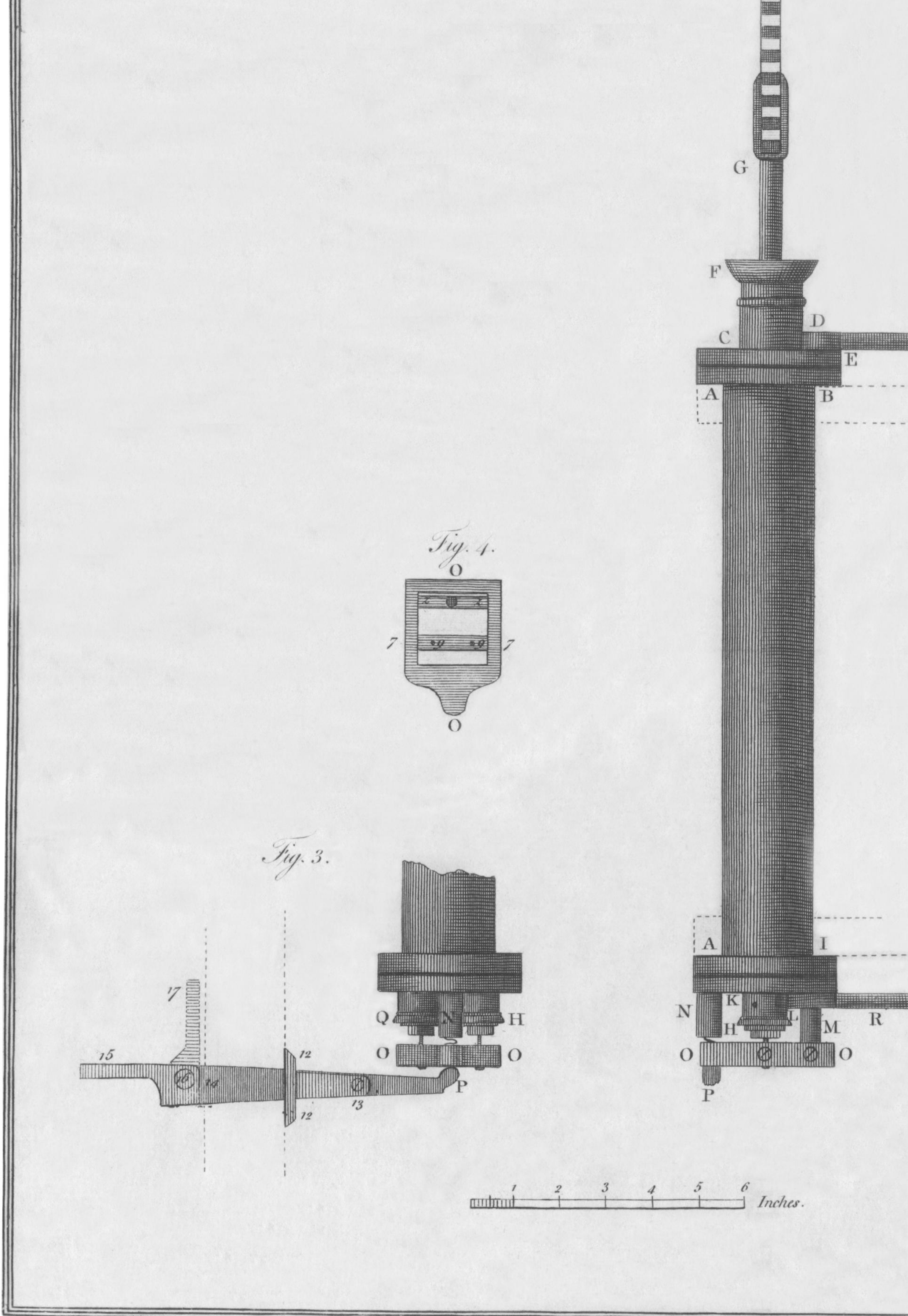

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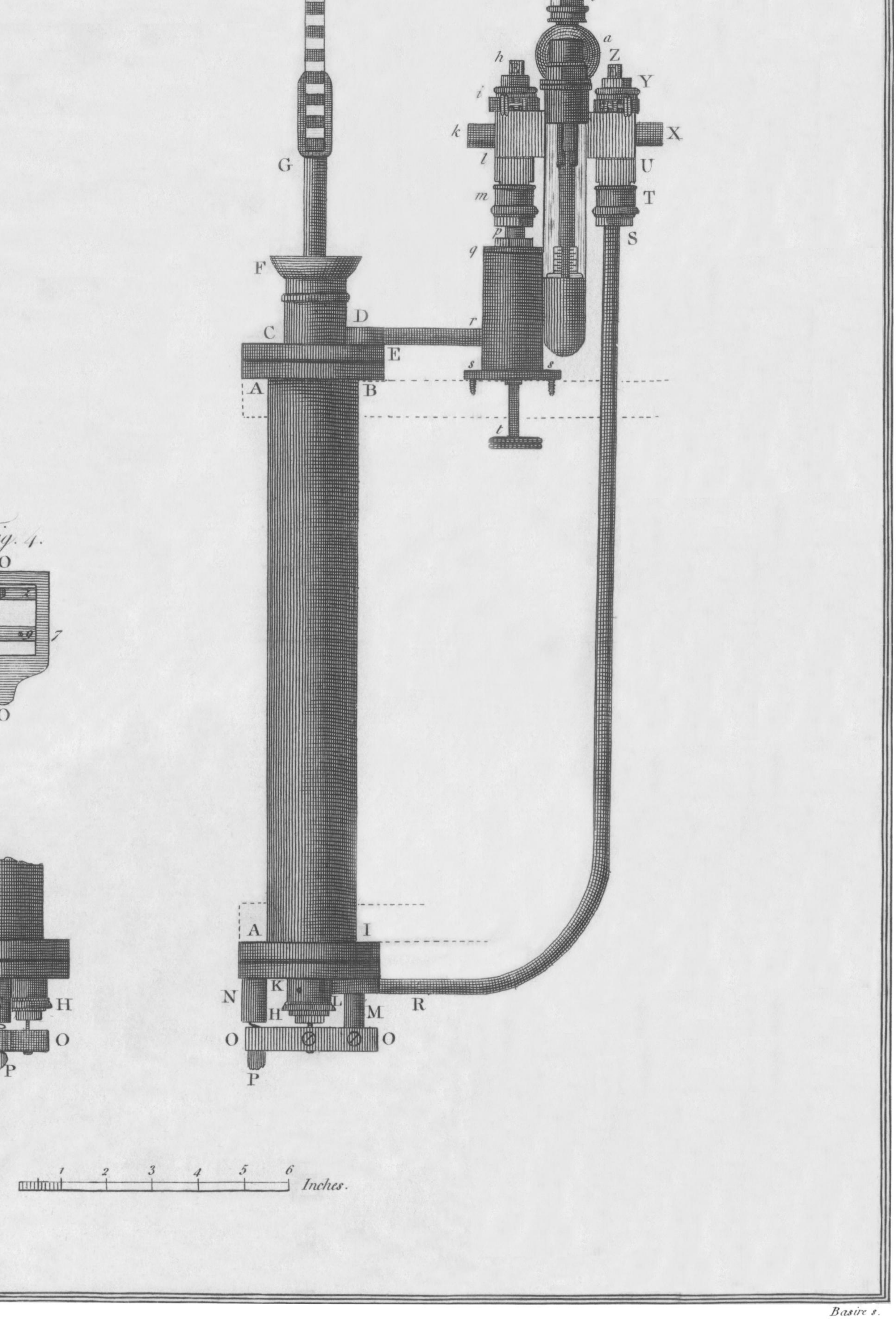
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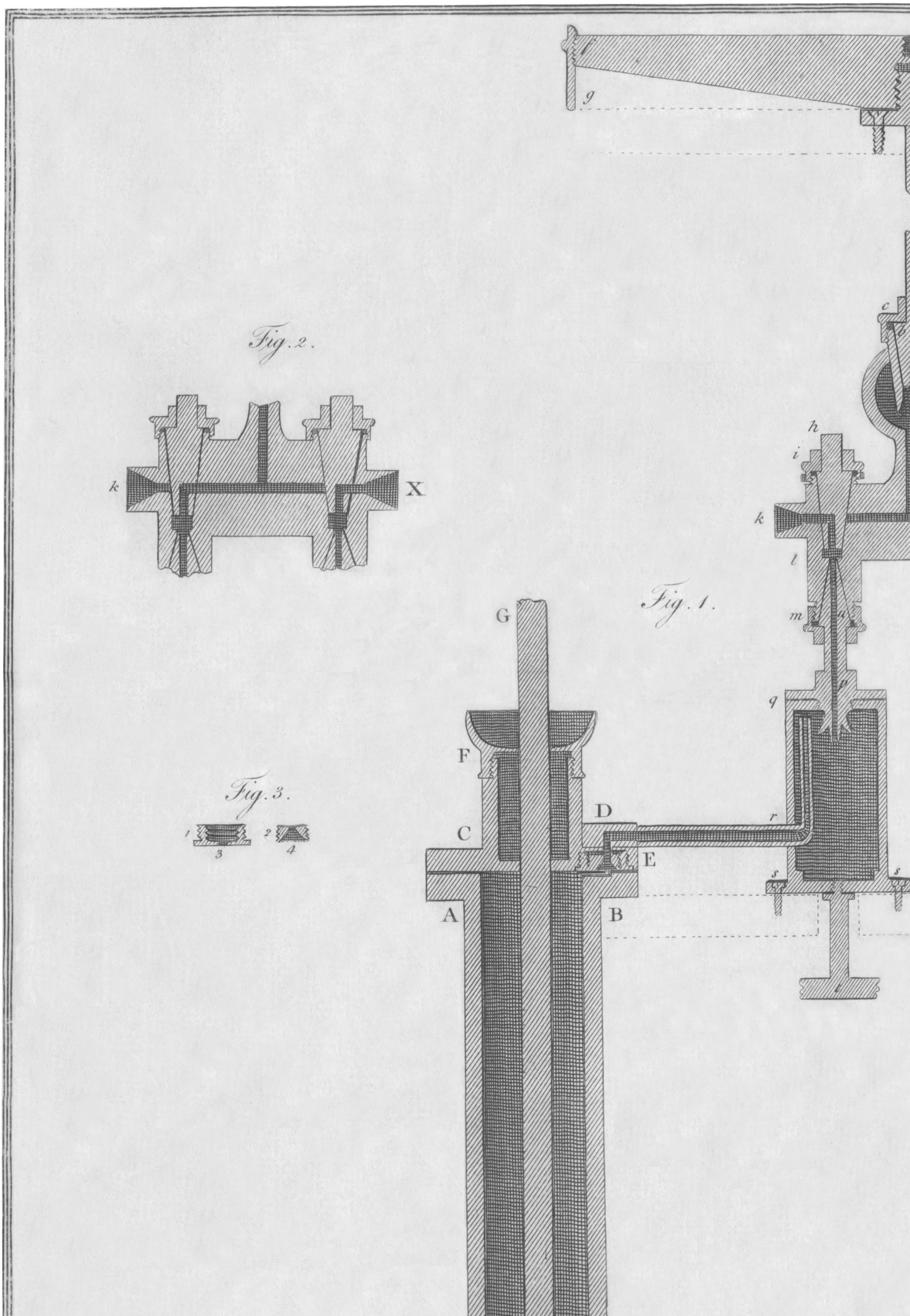

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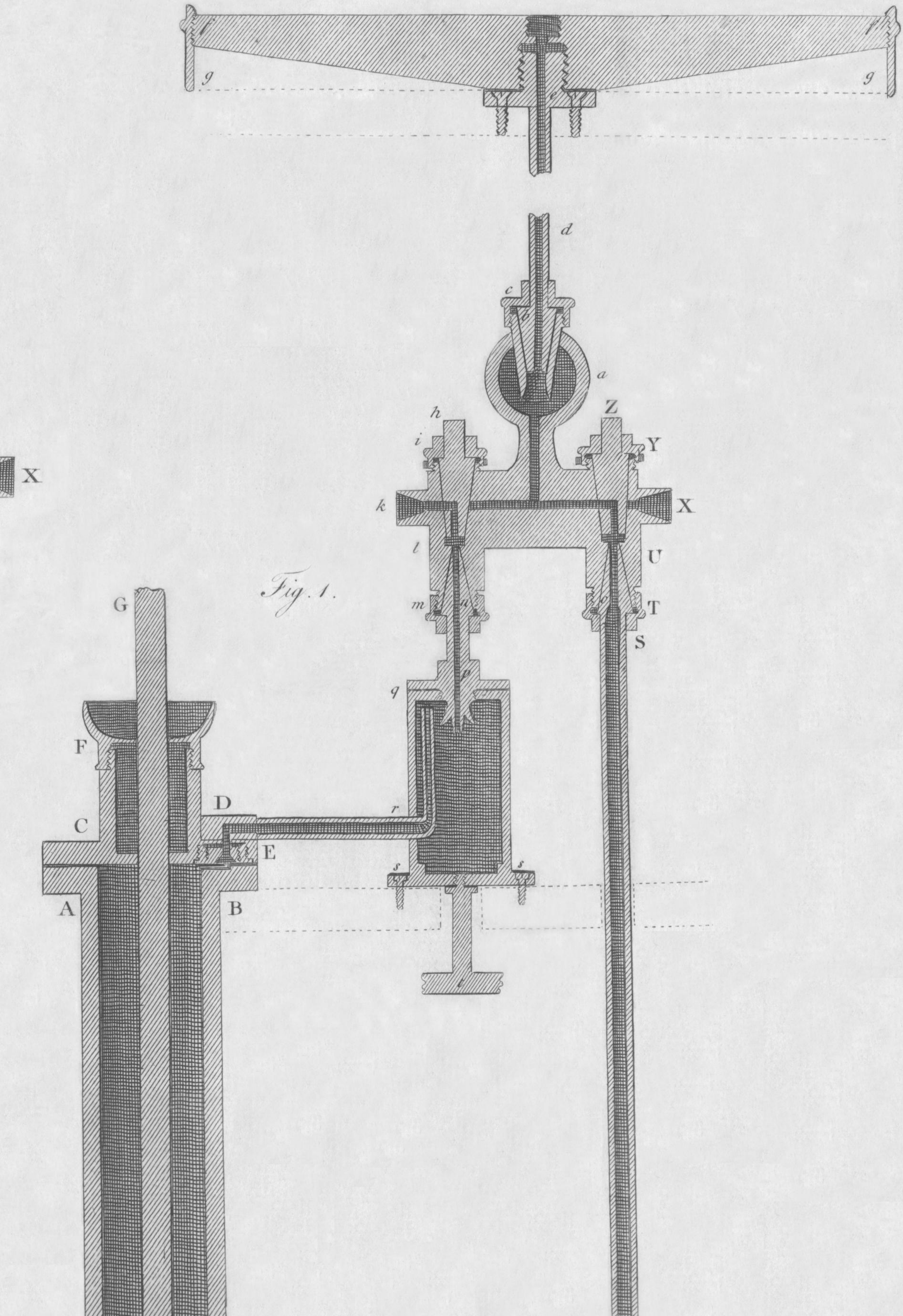
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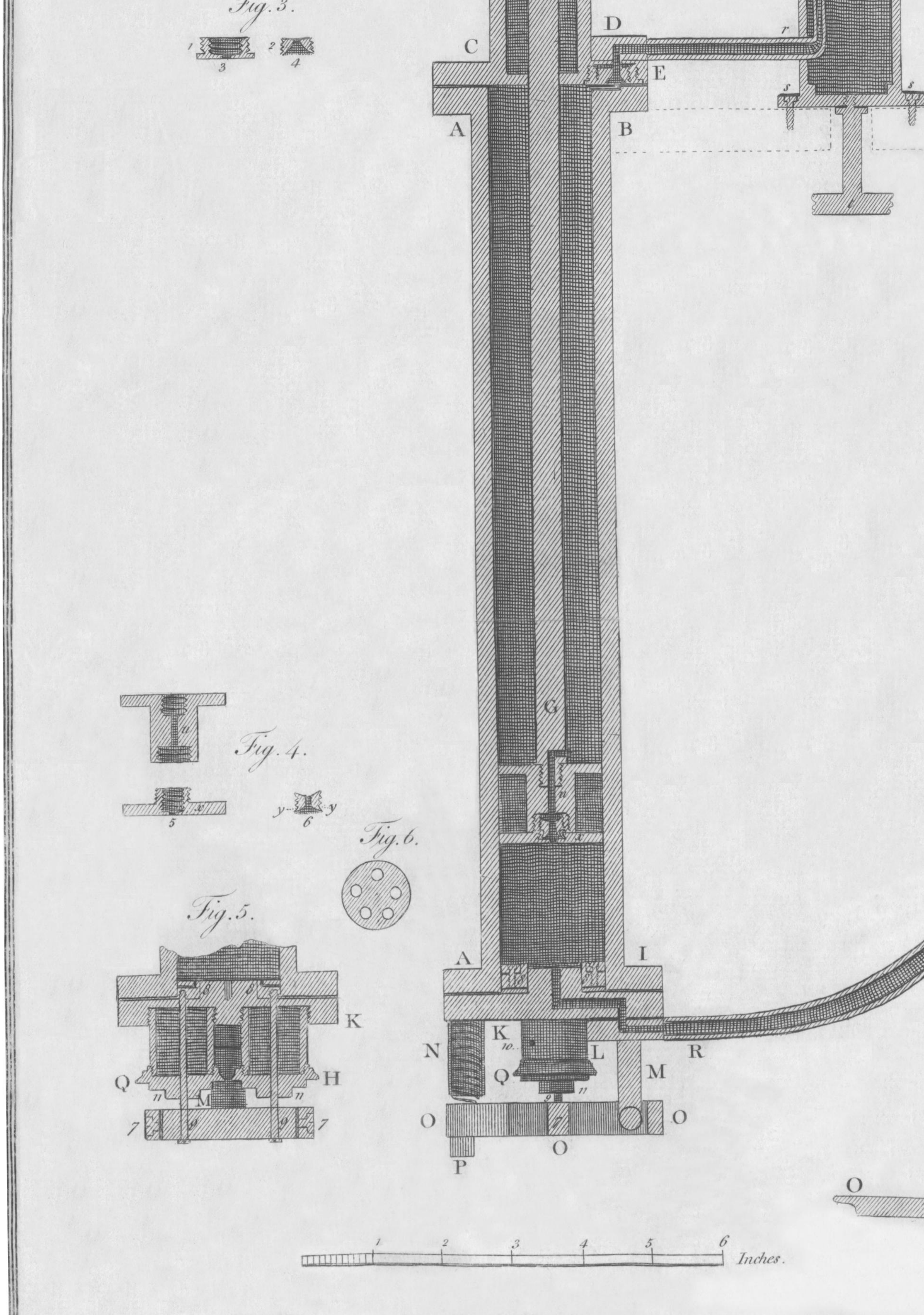

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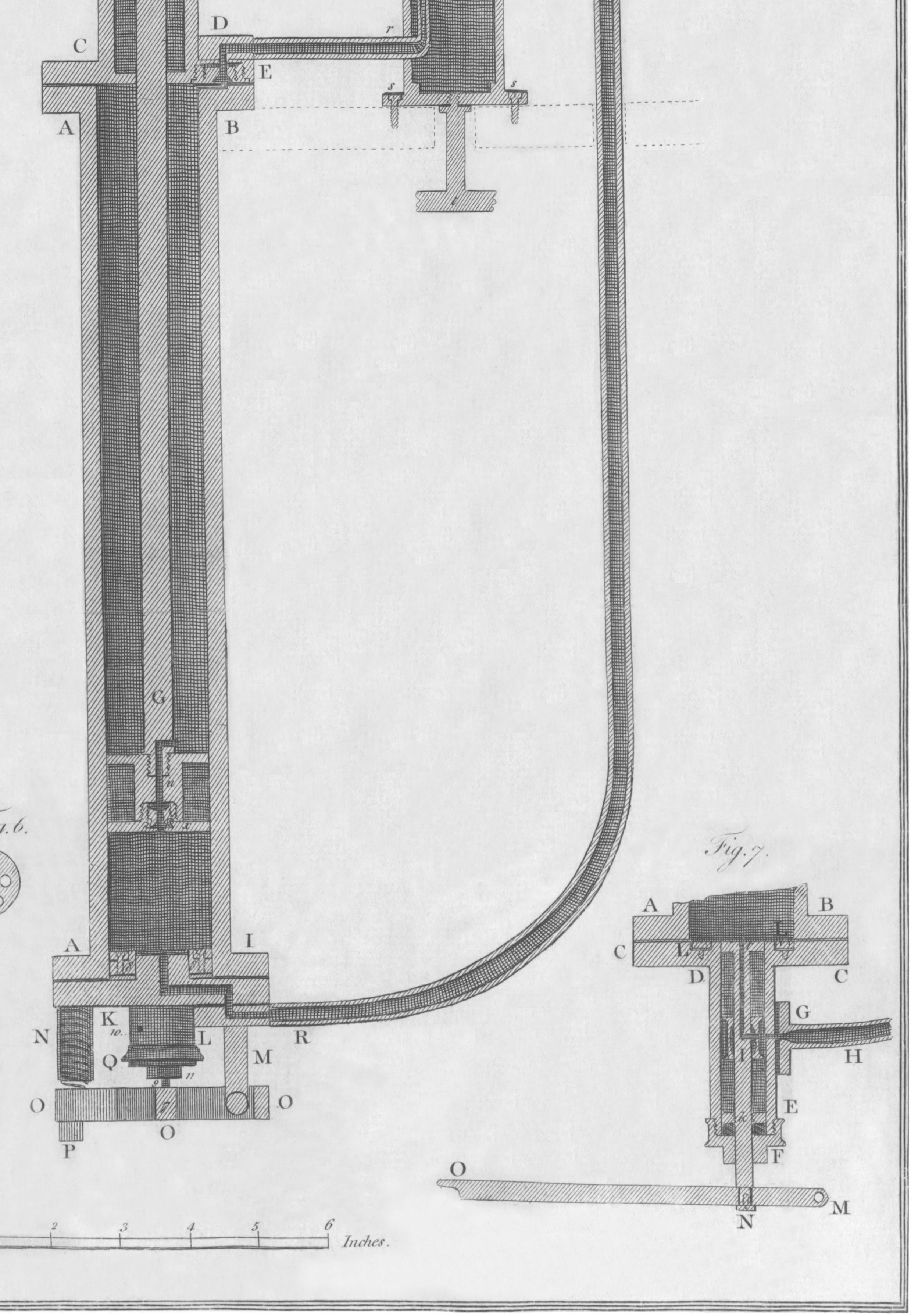

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